Note on Vacuum Photodiode Calibration at KEK

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PURPOSE

We have made a calibration of the vacuum diode photodiodes with pulsed neutron beam at KEK. Our goal is to make a calibration table for all the photodiodes before shipping to LANL.

APPARATUS

Experimental apparatus is shown in figure 1. Cd or In plates were located on a neutron beam line as the target. The flight path length from the ambient temperature light water moderator to the target was 10.5 m. The CsI scintillator was fixed ~15 cm from the target, and the photodiode was optically coupled to the CsI without optical grease or cement. The CsI scintillator, photodiode, and pre-amp were electrically and optically shielded. The pre-amp out was connected directly to a digital scope (Tektronix TDS 3052, DC coupling, impedance 1 MΩ) and can be recorded with time. Typical electric noise (pre-amp out) is shown in fig. 2.

MEASUREMENT

The photodiode response to the CsI scintillation was measured for Cd and In targets, and the pre-amp out signal averaged over 512 neutron beam pulses was recorded for each of 47 photodiodes and for two target materials. There were 48 photodiodes in total. The diameter of one photodiode (#213) was, however, slightly larger than that of the photodiode holder which was attached to the CsI scintillator, and the photodiode could not be mounted. Omitted the #213 photodiode, 47 photodiodes were calibrated. See figs. 3 and 4 for the pre-amp out signals as a function of time (TOF spectra) for the Cd and In targets. The proton beam intensity was monitored during the measurement. The beam intensity was stable at a level less than +/-2%. We used the tube #250 as a reference and measured the TOF spectrum several times during the calibration at 1-2 hour intervals. The TOF spectrum did not change very much. The variation was less than 3%.

ANALYSIS

The thermal neutron peak observed by the neutron radiative capture of Cd, the Cd cutoff (not a real peak), the 1.46 eV In resonance, and the 9.1 eV In resonance were used for the vacuum photodiode calibration. The peak heights were obtained by Gaussian fits. Figures 5-8 show correlations between the peak heights and the cathode current resulted from a 2856K tungsten lamp (the EIAJ.ET 61A standard).

RESULT

It was expected and confirmed that the photodiode responses to CsI scintillation for different targets had a strong correlation (fig. 7). The response to CsI was also found to have a rough correlation with that to a tungsten lamp (fig. 8). However, it was still quite different, and we cannot employ the tungsten lump calibration that was provided by Hamamatsu Photonics.

SUMMARY

1. The photodiode response to CsI scintillation measured at KEK with pulsed neutron beam was different from that to a tungsten lamp provided by Hamamatsu Photonics.
2. The responses varied from 0.4 to 1.1 in relative to that of the photodiode #250.
3. The relative responses to CsI scintillation for 47 vacuum photodiodes are listed in table 1 together with Hamamatsu Photonics data. The experimental error of this calibration was estimated less than 5%.

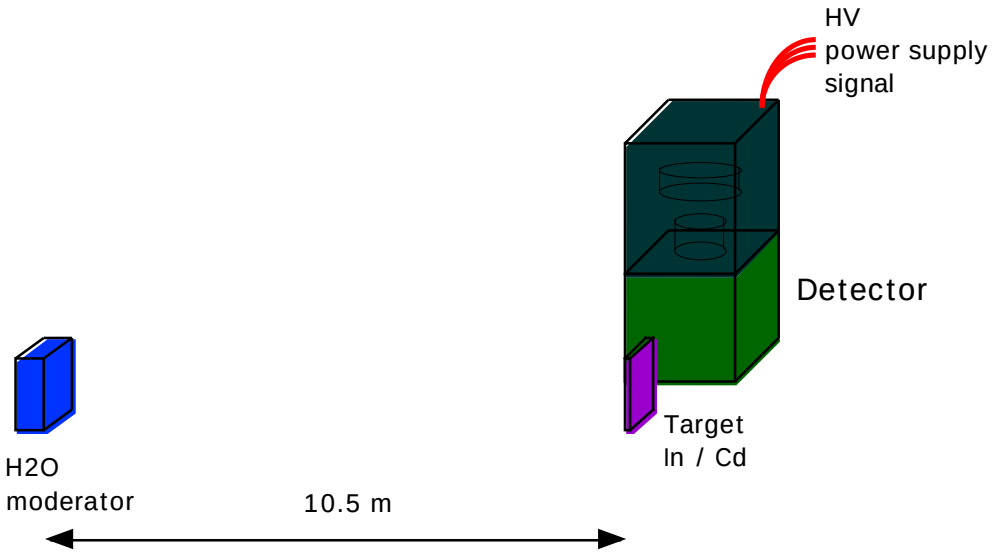

Figure 1 Flight path length from the light water moderator to the target was 10.5 m. The pre-amp out was directly connected to a Tektronix TDS3052 (DC coupling, impedance 1 MΩ). The target and the detector was ~15 cm apart.

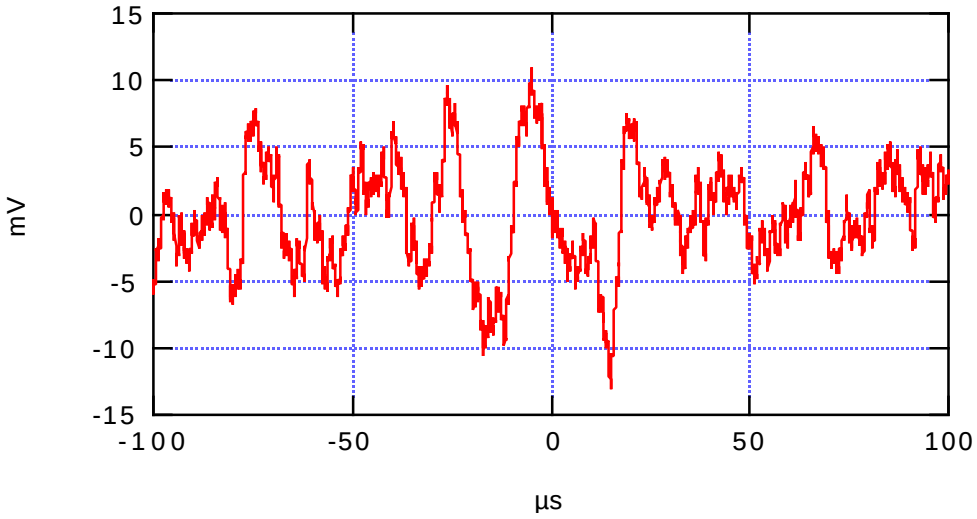

Figure 2 Typical electronics noise. The noise level is ~30 mV peak-to-peak or less than 5 mV in rms.

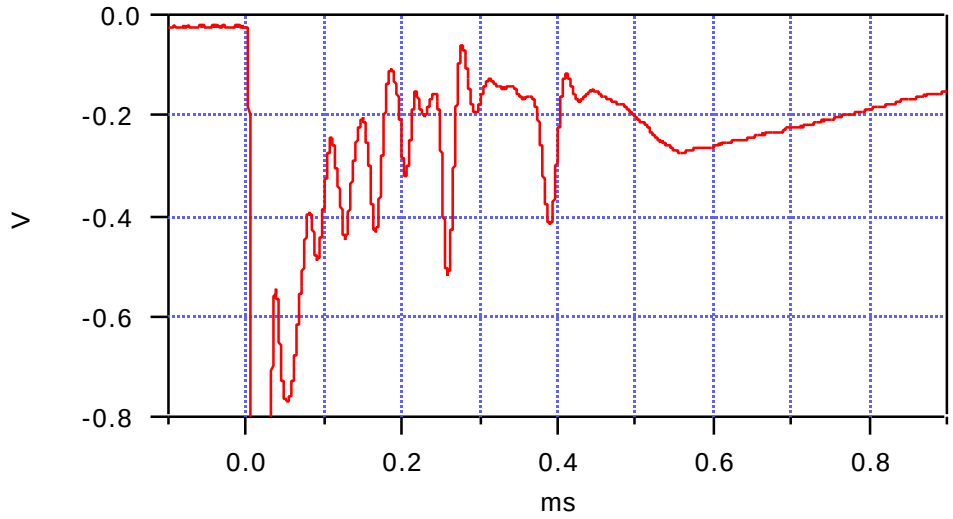

Figure 3 In capture gamma spectrum from measured by tube #250 (reference tube). The spectrum shown here is the average over 512 neutron pulses. For $t < 0$, a constant offset voltage was observed, which seemed due to the ground level difference between the pre-amp power supply and the digital scope. The peaks at $t = 0.39$ ms and $t = 0.26$ ms correspond to 1.46 eV and 9.1 eV resonances, respectively.

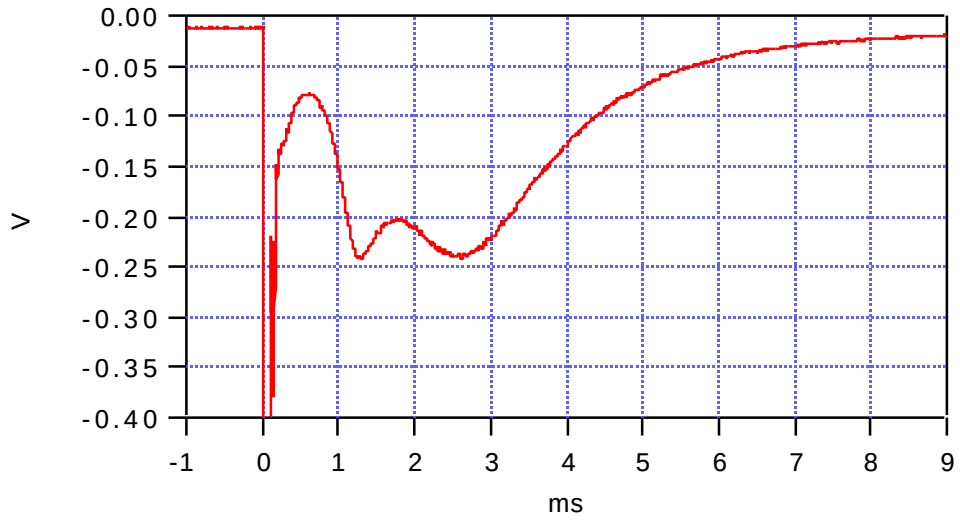

Figure 4 Cd capture gamma spectrum from measured by tube #250 (reference tube). The thermal neutron peak appeared at $t = 2.6$ ms. The peak at $t = 1.3$ ms is due to the Cd cutoff at ~0.4 eV. Resonance at 27.6 eV is also seen at $t = 1.5$ ms.

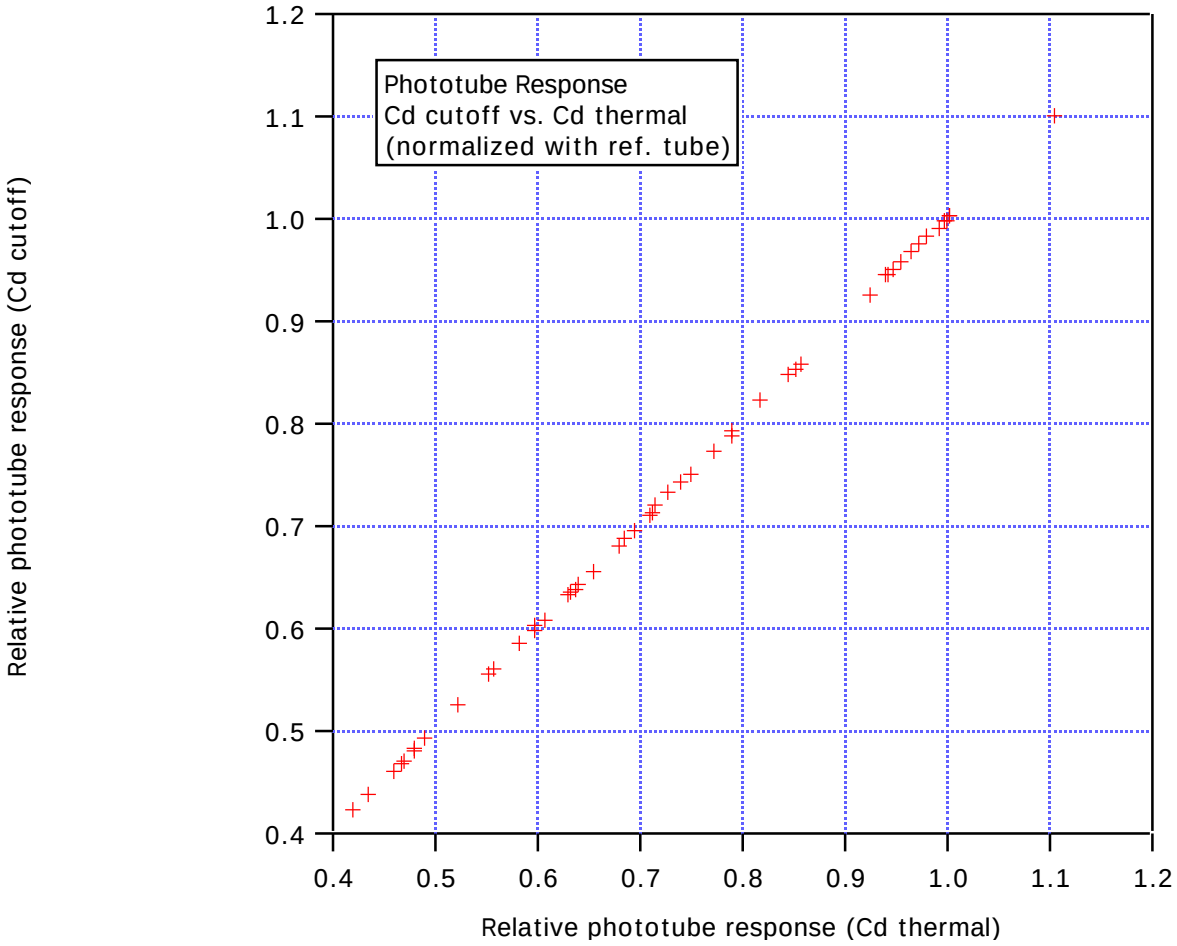

Figure 5 Peak height correlation between "Cd cutoff" and "Cd thermal" for 47 photodiodes. The peak height was normalized with that of the reference tube (#250). The deviation from "linearity" is less than 1% (the standard deviation σ is 0.004).

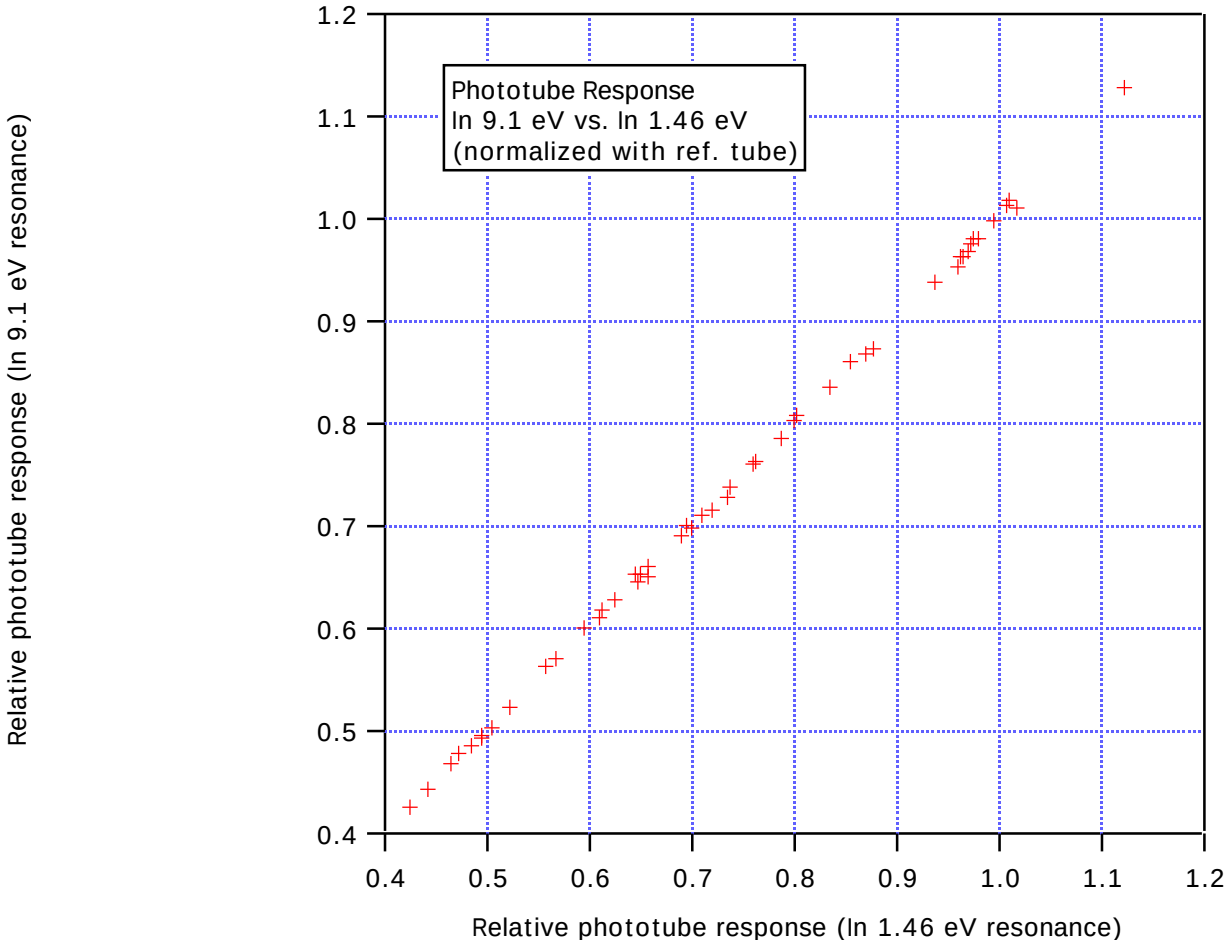

Figure 6 Peak height correlation between “In 9.2 eV resonance” and “In 1.46 eV resonance” for 47 photodiodes. The peak height was normalized with that of the reference tube (#250). The deviation from “linearity” is less than 1% ($\sigma = 0.007$).

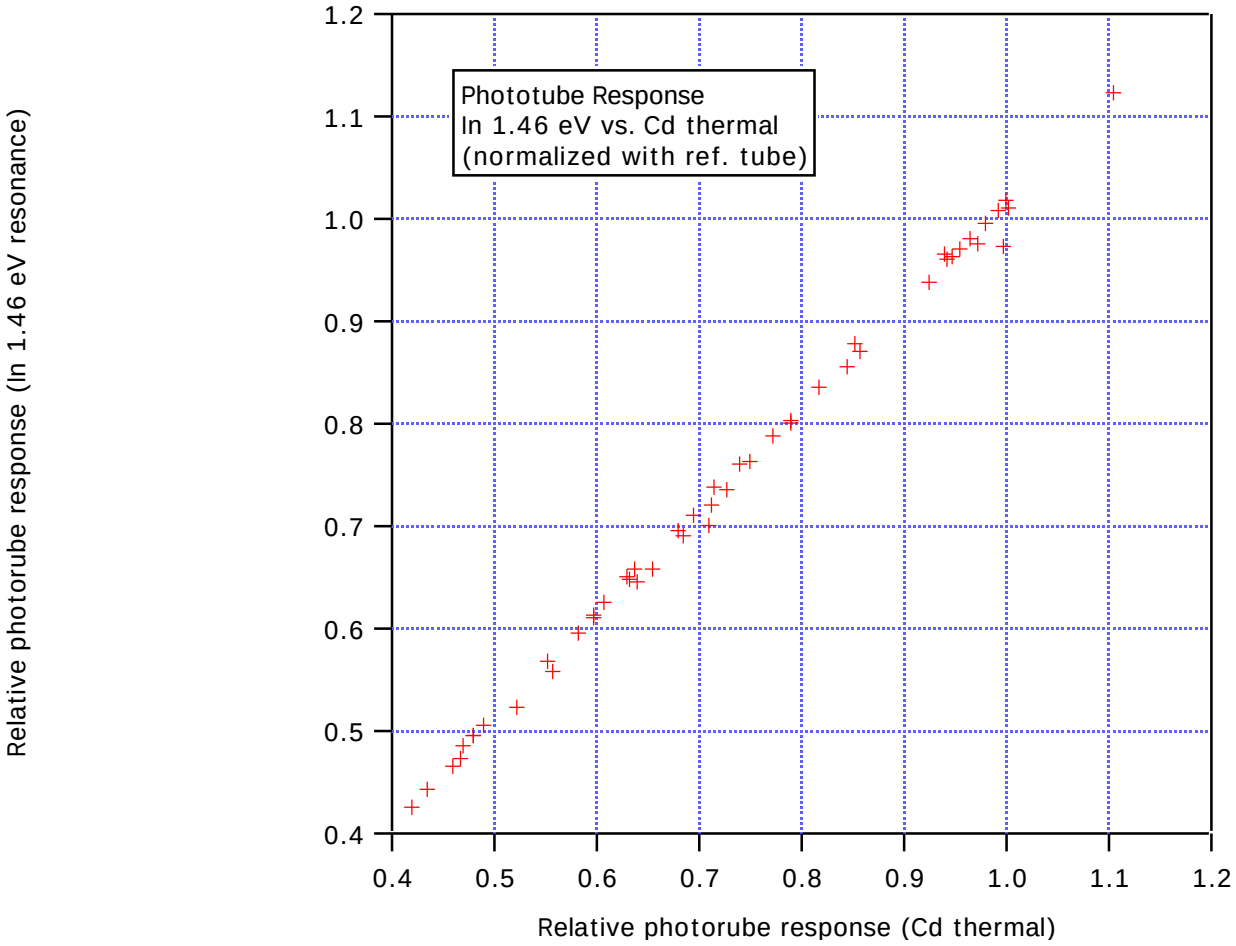

Figure 7 Peak height correlation between “In 1.46 eV resonance” and “Cd thermal” for 47 photodiodes. The peak height was normalized with that of the reference tube (#250). The mean and standard deviation of the ratio between both peak heights are 1.016 and 0.014, respectively.

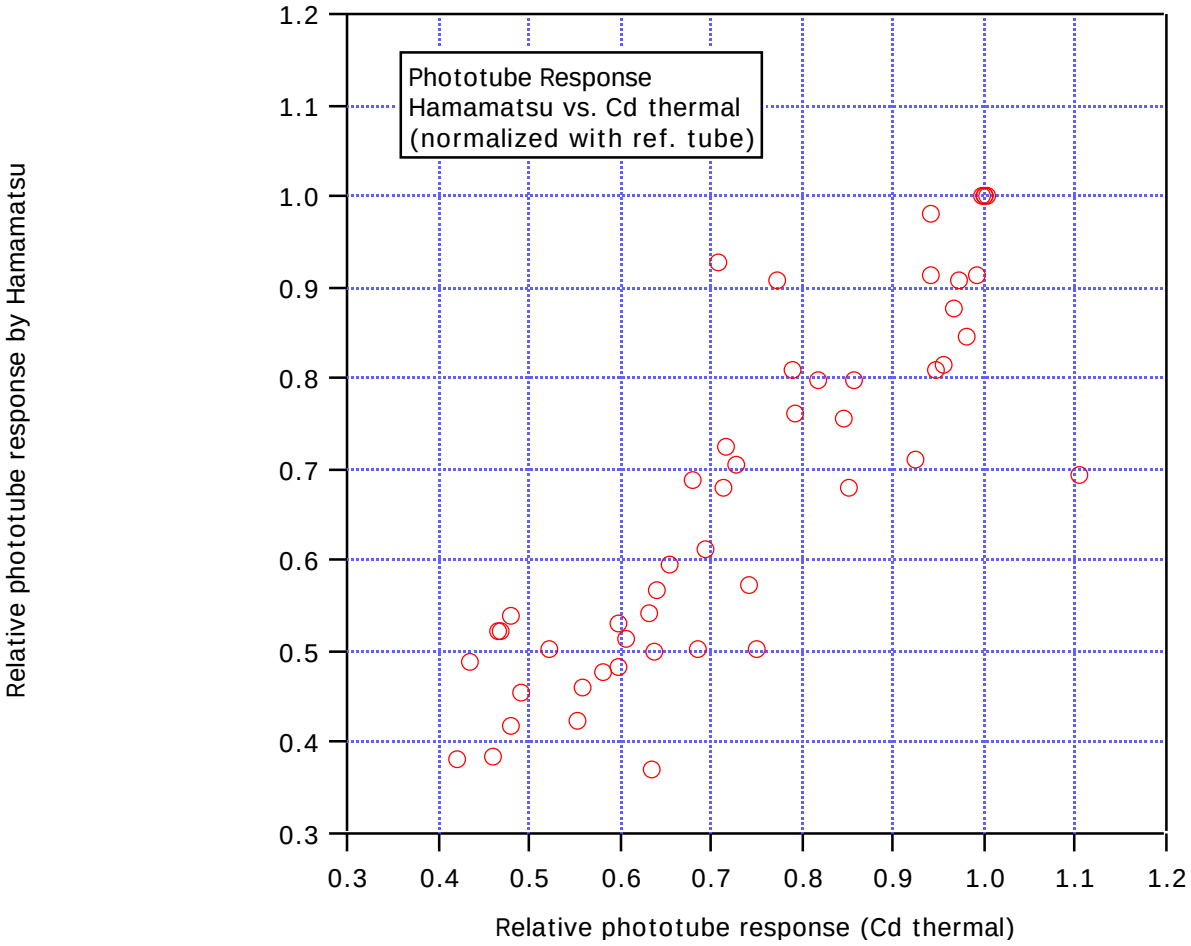

Figure 8 Peak height correlation between “Hamamatsu” (tungsten lamp calibration by Hamamatsu Photonics) and “Cd thermal” for 47 photodiodes. The photodiode responses were normalized with those of the reference tube (#250).

Photodiode #	KEK	Hamamatsu	
160	0.598	0.482	78.5
162	0.459	0.383	62.5
164	0.713	0.681	111
165	0.633	0.370	60.3
221	0.686	0.504	82.1
226	0.467	0.523	85.3
230	0.709	0.926	151
231	0.558	0.460	74.9
233	0.980	0.847	138
234	0.436	0.489	79.7
235	0.641	0.568	92.6
237	0.728	0.706	115
238	0.523	0.501	81.7
239	1.104	0.693	113
241	0.845	0.755	123
242	0.943	0.982	160
243	0.992	0.914	149
247	0.421	0.382	62.3
248	0.925	0.712	116
250	1.000	1.000	163
251	0.790	0.810	132
252	0.973	0.908	148
253	0.857	0.798	130
255	0.716	0.724	118
256	0.679	0.687	112
257	0.582	0.479	78.0
259	0.741	0.572	93.3
260	0.553	0.423	68.9
261	0.791	0.761	124
263	0.966	0.877	143

Photodiode #	KEK	Hamamatsu	
265	0.631	0.541	88.2
266	0.469	0.523	85.2
268	0.655	0.596	97.1
269	0.817	0.798	130
271	0.491	0.454	74.0
272	0.751	0.504	82.1
273	0.607	0.515	83.9
274	0.637	0.500	81.5
276	0.481	0.539	87.8
280	0.772	0.908	148
281	0.941	0.914	149
283	0.955	0.816	133
289	0.948	0.810	132
290	0.852	0.681	111
293	0.599	0.531	86.6
295	0.695	0.613	100
296	0.481	0.419	68.3

Table 1 The photodiode responses to CsI scintillation are tabulated with those measured with a tungsten lamp by Hamamatsu Photonics. "KEK" represents our calibration, and numbers are relative values to the reference photodiode (#250) response. The right numbers in column "Hamamatsu" are the absolute photo cathode current (μA/lm) provided by Hamamatsu Photonics, while those in the left column are the relative values.